MODELING OF POLLUTANT DISPERSION AND TRANSPORT OF AIR POLLUTANTS:

Plume approach has been modelled & represented as Gaussian Plume Approach (GPA) model. The expanding plume has a Gaussian or normal distribution of concentration in the lateral (y) & vertical (z) directions are represented in fig. 1.

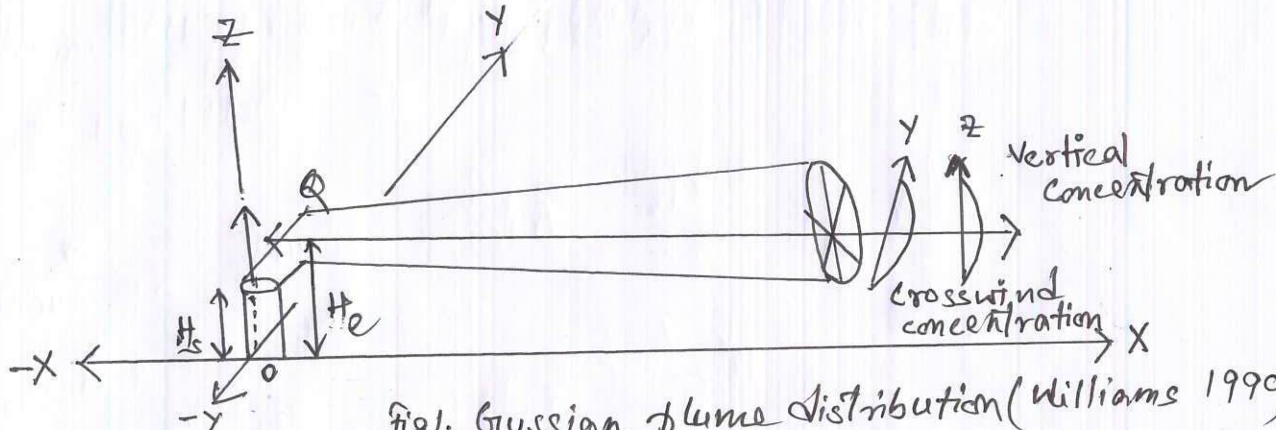

fig1. Gussian plume distribution (Williams 1990)

The concentration C ($\mu g/m^3$) at any point (x, y, z) is represented as -

$$C(x, y, z) = \frac{Q}{2\pi \sigma_y \sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left\{-\frac{(z-H_e)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z+H_e)^2}{2\sigma_z^2}\right\}\right] \rightarrow (1)$$

where,

Q = pollutant emission rate ($\mu g/sec$)

u = wind speed

x, y, z = along wind, cross wind & vertical distances

H_e = effective stack height (stack height + plume rise)

σ_y & σ_z are measurements indicating the extent of plume growth & in the Gaussian formula represent respectively, the standard deviations of the horizontal & vertical concentrations in the plume.

If $y = z = 0$, the equation above is reduced to:

$$C(x) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{H_e}{2\sigma_z^2}\right] \rightarrow (2)$$

(2)

The eq^n (2) indicates that ~~cont~~ concentrations are directly proportional to the rate of emission (Q). It is also evident that unless $H_e = 0$ (i.e., unless the source is at the level of the ground), the maximum conc. (C_{max}) will exist at a location downwind & this downwind distance will be more & more higher with increase in H_e, further the C_{max} value will be lowered with the increase in He. C_{max} is by & large proportional to H_e^{-2}.

Boyancy has been found to be responsible for the plume rise to a certain height above the point of emission. An imp. method of determining plume rise is 'Brigg's Plume Rise' method (G.A. Brigg's 'Plume Rise', US Atomic Energy Commission 1969). Here, plume rise (H) is written as:

$$\Delta H = 3.3 (Q_H)^{1/3} (10 H_s)^{2/3} U^{-1} \text{ for } Q_H \geq 20 MW$$

$$\Delta H = 20.5 (Q_H)^{0.6} (H_s)^{0.4} U^{-1} \text{ for } Q_H \leq 20 MW$$

Q_H = sensible heat emission from the stack

U = wind speed at the stack height (H_s).

Q_H is mostly assumed to be equal to 1/6 th of the total heat generated through combustion of the fuel.

In these, whole set of modeling, plume's standard deviation in vertical & lateral directions (σ_z & σ_y) are imp. & are influenced by the atmospheric turbulence in the boundary layer.

Now, the effect of the mixing height on vertical dispersion of plume is also taken into consideration in the equation given below & obtained by modification of eq^n (1) for ground level concentrations.

$$C(x) = \frac{q}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{H_e}{2\sigma_z^2}\right) + \exp\left\{-\frac{(2L-H_e)^2}{2\sigma_z^2}\right\}\right]$$

where L = mixing height

If $H_e > L$ when the conc. is zero (i.e., pollution is above the mixing height), this equation is invalid.

All the pollutants emitted by point as well as dispersed sources are transported, dispersed & concentrated by topological, meteorological & biological conditions. The air mediated transportation is initiated with the emission of pollutants from the source. These materials diffuse through the atmosphere & are deposited on living organisms & non-living objects. Some pollutants are either actively or passively absorbed by organisms. Pollutants dispersion in the atmosphere is due to following imp. mechanisms.

(i) The general mean air motion responsible for transportation of pollutants down-wind.

(ii) The fluctuation of wind velocity creating turbulence that disperse pollutants in almost all directions.

(iii) Concentration gradients causing mass diffusion of pollutants.

Aerodynamic characteristics of pollutants like shape, size, weight etc. also determine in great way the rate of dispersal & settlement of particulate matter. The most significant features of pollutants transportation are as follows—

(1) Atmospheric conditions:

This is imp. in the production of secondary pollutants. Suitable atmospheric condition permits the production of secondary pollutants like PAN & O_3 through photochemical reactions. Atmospheric situations play the key role in smog formation.

<2> Differential heating of air :

The differential heating of the air above land & sea from the equator to the pole results in formation of horizontal pressure gradients & leads to horizontal atmospheric motion. Thus, wind circulation & air movement are largely dependent on the temp. differences between the polar atmosphere & the equatorial atmosphere, between oceanic atmosphere & continental atmosphere. Wind behaviour is of much importance to govern the speed & direction of pollutant dispersion. An industry is set up in any*

<3> Humidity :

Increase in humidity in the atmosphere leads to acidity & creates aerosol problem. H_2O vapour is adsorbed by particulates. SO_2 reacts with water vapour to form H_2SO_4; NO_2 also reacts with water vapour to give rise to HNO_3, both the acids may contribute to acid rain.

* region only after a generalized study of wind direction of the region throughout one annual cycle.